THE STATUS OF *YOMA ALGINA* (BOISDUVAL, 1832) AND *Y. SABINA* (CRAMER, 1780) (LEPIDOPTERA: NYMPHALIDAE: NYMPHALINAE) IN AUSTRALIA

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Abstract

Yoma Doherty, 1886 (Nymphalinae: Junoniini) comprises two species, *Y. algina* (Boisduval, 1832) and *Y. sabina* (Cramer, 1780), which we confirm in this study by using larval morphology and colour pattern, pupal morphology, adult morphology (*i.e.* wing pattern elements, wing colour, fore and hindwing shapes, male genitalia) and host plant specialisation (*Y. algina* restricted to *Hemigraphis* spp: Acanthaceae). In total, we determine at least 22 phenotypic character state differences between the two species and, in addition, confirm that both species occur in Queensland. In Australia, *Y. sabina* occurs in the Top End of the Northern Territory, throughout Torres Strait and from eastern Queensland from Cape York to Townsville, while *Y. algina* is now confirmed to naturally occur in Queensland, currently known only on the east coast of Cape York Peninsula from Somerset at Cape York to Peach Creek, 25 km NNE of Coen. The subspecific status of Australian populations of *Y. algina*, tentatively assigned to *Y. a. netonia* Fruhstorfer, 1912, will remain in doubt until more Australian material is collected. Butterfly house populations of *Y. algina* in eastern Australia have existed since the late 1980s but were confused with *Y. sabina* for many years. These populations are thought to originate from a single female collected at Iron Range, Cape York Peninsula. Thus, the existence of *Y. algina* in Queensland has led to confusion in regards to the life history of *Y. sabina*. A review of *Y. s. sabina* from Papua New Guinea and *Y. s. parva* (Butler, 1876) from mainland Australia, including Torres Strait, indicates that the two taxa do not differ phenotypically. In addition, the original description of *Y. s. parva* was found to be based on a diminutive 'dry season form', which is atypical of normal *Y. sabina* from Australia. Thus, because of the phenotypic continuity of *Y. sabina* through Papua New Guinea into Australia and confusion with the nomenclature of the Australian population caused by Butler, we regard *Y. s. parva* syn. nov. as a junior synonym of *Y. s. sabina*. In addition, the diminutive 'dry season form' of *Y. s. sabina* occurring in Papua New Guinea and Australia is here proposed as form *parva* stat. rev.

Introduction

The genus *Yoma* Doherty, [1886] occurs widely in the Oriental and Australian Regions (d'Abrera 1978, Parsons 1998). *Yoma sabina* (Cramer, [1780]) is a lowland butterfly (Igarashi 1985), which has a broad distribution from Myanmar to Hong Kong in southern China, Taiwan, the Philippines, through Thailand to Indonesia, the Moluccas, mainland New Guinea and, within Australia, from Torres Strait into tropical mainland Queensland and the Northern Territory (Bingham 1905, Tsukada 1985, Parsons 1998, Bascombe *et al.* 1999, Braby 2000, Ek-Amnuay 2006). The type locality of *Y. sabina* is Ambon Island in the Moluccas, Indonesia (Edwards *et al.* 2001, Parsons 1998).

Yoma algina (Boisduval, 1832), which is considered to be a second species (d'Abrera 1978, Parsons 1998), in contrast is much more restricted in its distribution, occurring predominantly in the New Guinea region from Waigeo

Island through to the Solomon Archipelagos and Vanuatu (Parsons 1998, Tennent 2002). The type locality of *Y. algina* is 'New Guinea' (Parsons 1998) but is thought to be more precisely Waigeo Island in West Papua Province, Indonesia (Fruhstorfer 1912-15).

All of the recent major works on Australian butterflies (Common and Waterhouse 1972, 1981, Braby 2000, Orr and Kitching 2010) have the genus as monotypic and consisting of just one species, *Y. sabina*, with *Y. algina* a subspecies of *Y. sabina* occurring in New Guinea. Fruhstorfer (1912-1915), Barrett and Burns (1951), d'Abrera (1978) and Tennent (2002), however, considered the two taxa to be specifically distinct. This distinction was supported by Parsons (1998), who reported collecting both taxa in Papua New Guinea flying together at several locations, including Port Moresby. Thus he considered the two taxa to be separate species and sympatric in their occurrence, at least in some areas.

Both taxa are highly variable in their underside wing markings. Thus, Parsons (1998) suggested eight subspecies of *Y. algina* in Papua New Guinea, with *Y. a. netonia* Fruhstorfer, 1912 occurring in southern Papua New Guinea and *Y. s. sabina* occurring in New Guinea and the Moluccas (Tsukada 1985, Parsons 1998). In Australia, *Y. s. parva* (Butler, 1876) occurs in the Wet Tropics of Queensland, on Cape York Peninsula, on several Torres Strait islands and in localised areas in the Northern Territory (Braby 2000).

On mainland Queensland, *Y. s. parva* can be generally uncommon in the southern end of its range in the Wet Tropics but, further north, it is observed more frequently: at Cooktown (Valentine 1988) and particularly in Torres Strait (Braby 2000, T.A. Lambkin unpublished data), especially on Thursday Island (Valentine 1988). The species frequents lowland rainforest, open forest bordering rainforest (G. Sankowsky pers. comm.) and monsoon forest (Braby 2000). In addition, it is found in swampy areas (Valentine 1988) and in upland rainforests of the Atherton Tableland (Olive 1978). Overall, the species is mostly observed during or just after the wet season. Adult males fly along sunlit tracks defending territories and perch (Valentine 1988) with wings outspread, normally within 2-5 m from the ground (Braby 2016). Females of *Y. sabina* are often observed flying low over the forest floor in search of oviposition sites on or near low-growing herbaceous host plants (Saguru and Haruo 2000, Braby 2016). Adults are also found within the forest settled on the underside of foliage and, in these situations, are often difficult to detect due to their cryptic underside colouring. In addition, *Y. sabina* is known to aestivate in large numbers throughout the dry season in Cape York Peninsula and Townsville, clustering in dense vines, caves and old buildings (Sankowsky 2015, Braby 2016, P.S. Valentine pers. comm.).

Parsons (1998) and Tennent (2002) noted that adults of *Y. algina* frequently perch along sunlit tracks and clearings in rainforest habitats.

The life history of *Y. s. sabina* from Papua New Guinea was described by Szent-Ivany and Carver (1967) and Parsons (1998). From the Moluccas, Saguru and Haruo (2000) illustrated the egg and final instar of *Y. s. sabina*. In Australia, the life history of what was believed at the time to be *Y. s. parva* but found here to be that of *Y. algina* was described from material collected at Iron Range, Cape York Peninsula in Queensland (Wood 1987a).

Saguru and Haruo (2000) reported observing a female of *Y. s. sabina* ovipositing on the ground (in the Moluccas) and the egg was successfully reared to an adult on *Gendarussa vulgaris* Nees. (a synonym of *Justicia gendarussa* L.) (Acanthaceae). Additionally, Saguru and Haruo (2000) observed females of *Y. s. podium* Tsukada, 1985 in Taiwan, ovipositing on *Blechum pyramidatum* (Laam.) Urb. (Acanthaceae). Sankowsky (2015) added that larvae of *Y. s. parva* usually rest on the ground when not feeding.

There is little published on the early stages of *Y. algina* apart from a photograph of a larva, indicated to be instar 3, in Parsons (1998).

In Australia, Wood (1987a) successfully reared larvae of what he thought at the time to be *Y. s. parva* on what he believed to be a *Ruellia* sp. (now syn. of *Dipteracanthus* Nees) (Acanthaceae). Later, Sankowsky (1991) confirmed *D. bracteatus* (R.Br) (Acanthaceae) as a larval host plant for *Y. s. parva* at Iron Range.

In Papua New Guinea, Szent-Ivany and Carver (1967) reared *Y. s. sabina* on *Hemigraphis reptans* (G.Forst.) T. Anderson ex Hemsl. (Acanthaceae), while Parsons (1998) provided a detailed description of the early stages of *Y. s. sabina* but did not mention a larval host plant.

Yoma s. parva, until recently, was rarely encountered in the Wet Tropics of Queensland but of late it has been observed more frequently due to the widespread increase of its host plant (*Dipteracanthus* spp) in the area (J. Olive pers. comm.). In early 2004 it became established in Townsville (Valentine 2004, 2005), where it still occurs in 2016 (P.S. Valentine pers. comm.). The availability of *Y. s. parva* from near populated areas in recent years has made possible a closer examination of its life history, thereby enabling a better comparison with that of *Y. algina* reared in butterfly houses in eastern Australia.

Since the late 1980s, what was considered to be *Y. s. parva* has been reared in many butterfly houses along the east coast of Australia. The initial stimulus for the current study was in 2008, when one of us (RK) attempted to feed larvae of what was then thought to be a butterfly house population of *Y. s. parva* on *D. prostatus* (Poir.) Nees. [syn *R. prostata*]. This attempt was unsuccessful and puzzling since *Dipteracanthus* spp were the known larval hosts for *Y. s. parva* (Sankowsky 1991), yet none of the larvae would feed and all subsequently died. Consequently, this led to additional investigation of the two taxa.

Based on the current study, it is now apparent that these butterfly house populations of *Yoma* are not *Y. sabina* but are a separate species, *Y. algina*. This raised questions in regards to where in Australia the original culture material was derived or did it somehow originate from New Guinea stock. The exact origin of the original culture material that was used to commence these in-house butterfly populations is unknown but it is likely that it originated from a single female from Cape York Peninsula (G. Sankowsky pers. comm.). In addition, this current study of the life histories of both taxa has now indicated that the life history observations of Wood (1987a) were of *Y. algina*, not *Y. s. parva* as he supposed. Moreover, his larval host plant identification was also incorrect (Wood 1987a), as larvae of *Y. algina*, as reported here, are restricted to *Hemigraphis* spp and do not feed on *Dipteracanthus* spp (syn *Ruellia* spp).

As a result of an investigation of both taxa, described in this paper, *viz.* wing pattern elements, species' distributions, larval host plant preferences, immature stage morphologies and structures of male genital armature, we confirm that there are two species of *Yoma* and that both species naturally occur on mainland Australia. We also remove the confusion surrounding the immature stages of both species by describing and illustrating the life history of both in full for the first time. Thus, we unravel the confusion that has surrounded these two species in Australia since the 1980s and further revise the taxonomic status of *Y. sabina* in Australia.

Materials and methods

Rearing of immature stages and comparison of larvae and pupae

The immature stages of *Y. s. parva* were reared from eggs supplied ex wild-caught females collected from the Wet Tropics, Queensland. Those of *Y. algina* were reared from eggs supplied by the Melbourne Zoo ex butterfly house population. Eggs of both species were reared to instar 3 in clear plastic, round food containers (280 ml; 50 mm high, bottom radius 42 mm, top radius 55 mm) on the following plant material: *Y. s. parva* on *D. prostatus*, *H. alternata* (Burm.f.) T. Anderson and *H. ciliata* S. Moore, and *Y. algina* on the two *Hemigraphis* spp.

Larger larvae (instars 4 and 5) were later transferred to potted host plants in mesh cages (840 high x 480 x 400 cm). Larvae pupated beneath leaves or stems of the host plants, on the overhangs of pot plants, or on the ceilings of mesh cages. All life history studies were conducted in Brisbane during February and March at ambient conditions (*i.e.* max/min temperatures of approximately 32/22°C). Each instar of both species was described, measured and photographed. To determine any differences between the larvae and pupae of the two species, final instar larvae and pupae of *Y. s. parva* (n = 24) and *Y. algina* (n = 18) were compared.

Comparison of wing pattern elements among adults

To determine the extent of phenotypic variation between the two species, wing pattern, including colours and spotting, plus wing shape, were subjectively compared among 78 specimens of *Y. s. parva* (42♂♂, 36♀♀) from Queensland, 16 specimens of *Y. s. parva* (5♂♂, 11♀♀) from the Northern Territory, 29 specimens of *Y. s. sabina* (21♂♂, 8♀♀) from Papua New Guinea; 18 specimens of *Y. algina* (8♂♂, 10♀♀) ex butterfly house culture, 10 specimens of *Y. algina* (6♂♂, 4♀♀) wild caught in Queensland and eight specimens of *Y. a. netonia* (6♂♂, 2♀♀) from Papua New Guinea.

Request for data from butterfly collections

Commencing in 2009, requests with attached figures of both taxa were disseminated throughout the butterfly collecting fraternity (n = 8) and public museums (n = 4) for information concerning *Yoma* specimens in their possession. In brief, the requests carried images of both species, male and female, and the recipients were requested to use wing pattern elements and wing shape to discern if *Y. algina* existed in any of their collections (the specifics of this request are provided in Appendix I).

Comparison of male genitalia

The genital armature of three males of each taxon (*i.e.* 2♂♂ from Australia and 1♂ from Papua New Guinea) were dissected from the abdomens and prepared for examination. Each abdomen was treated with 10% (w/v) aqueous potassium hydroxide (KOH) for 24 hours at room temperature, similar to the method used by Braby (2000). Clarified genitalia were then stored in glycerol and examined unmounted using a stereomicroscope. From these examinations the genital armature of a representative of each taxon was chosen and photographed, then structural comparisons were made between the two taxa. Male genitalia examined of *Y. s. parva* were from Malanda and Thursday Island, Queensland; those of *Y. s. sabina* were from Kapa Kapa, Central Province, Papua New Guinea; and those of *Y. algina* were from the Melbourne Zoo Butterfly House (2♂♂). In addition, male genitalia were examined of one *Y. a. netonia* from Rigo, Central Province, Papua New Guinea. Nomenclature of genital structures follows Braby (2000) and Monastyrskii (2011).

Abbreviations

Repositories of material examined: AM – Australian Museum, Sydney; ANIC – Australian National Insect Collection, Canberra; CGMC – Collection of C.G. Miller, Lennox Head; GRFC – Collection of G.R. Forbes, Brisbane; HUC – Collection in Harvard University, Cambridge, MA, USA; MV – Museum of Victoria, Melbourne; QM – Queensland Museum, Brisbane; TLIKC – Joint collection of T.A. Lambkin and A.I. Knight, Brisbane; WJC – Collection of W. Jenkinson, Beaudesert.

Names on labels: AA – A. Atkins; AIK – A.I. Knight; CGM – C.G. Miller; CWM – C.W. McCubbin; EDE – E.D. Edwards; EM – E. Mann; GAW – G.A. Waterhouse; GBM – G.B. Monteith; GD – G. Daniels; GD&MAS – G. Daniels and M.A. Schneider; GRF – G.R. Forbes; GW – G. Wurtz; HR – H. Rauber; JAK – J.A. Kershaw; IFBC&MSU – I.F.B. Common and M.S. Upton; JCLS – J.C. Le Souef; JFD – J.F. Donaldson; JO – J. Olive; JWCD – J.W.C. D'Apice; LR – L. Radunz; MDB – M. De Baar; MSM&BJM – M.S. Moulds and B.J. Moulds; OBL – O.B. Lower; PZ – P. Zborowski; RGE – R.G. Eastwood; TAL – T.A. Lambkin; TAW&IDN – T.A. Weir and I.D. Naumann; THG – T.H. Guthrie; WBB – W.B. Barnard; WJ&DB – W. Jenkinson and D. Bell; WJ&RKP – W. Jenkinson and R.K. Poulier.

Material examined

Yoma sabina parva (Butler, 1876)

QUEENSLAND: 1♀, Bamaga, Cape York, 28.iii.1964, IFBC&MSU (ANIC); 1♂, Batavia Downs, Cape York Peninsula, 13-19.i.1993, PZ (ANIC); 1♀, Cairns, captive bred Indooroopilly, Brisbane, 30.xii.2008, TAL (TLIKC); 1♀, same data except AA185; 1♂, Cape York, (QM); 1♂, same data except (ANIC); 1♀, Cape York, 19.x.1927, WBB (QM); 1♂, 1♀, Captain Billy Creek road junction, Cape York Peninsula, 11°41'S 142°42'E, 15.iii.1992, GD&MAS (QM); 1♂, Claudie River, 25.v.1974, JWCD (ANIC); 1♂, Chillagoe, OBL (QM); 1♀, Coen, Cape York Peninsula, 9-16.vii.1971, GBM (QM); 2♂♂, Cooktown, 20.iv.1922 (ANIC); 2♂♂, 2♀♀, same data except 2.viii.1979 (2♂♂), 7.vii.1964 (♀), 8.vii.1964 (♀), JCLS (ANIC); 2♂♂, 2♀♀, 35 km NW of Cooktown, 7.v.2003, WJ&DB (WJC); 1♂, Dauan Island, Torres Strait, 18.i.2004, TAL (TLIKC); 1♂, same data except 11.ii.2015 (TLIKC); 1♂, 2♀♀, same data except 12.ii.2015; 1♀, Gordon Creek area, Iron Range, Cape York Peninsula, 1.vii.1982, GD (QM); 3♂♂, 2♀♀, Green Hill, Thursday Island, Torres Strait, 23-31.vii.1983, TAL (TLIKC); 1♂, 1♀, same data except 20.ii.1994; 3♂♂, 1♀, same data except 24.ii.1994; 1♂, 1♀, same data except 24.iii.1994; 1♀, same data except 9.iii.2001; 1♀, same data except 3.iii.2004, AIK; 1♀, same data except 27-29.iii.1987, MDB; 1♂, Heathlands, Cape York Peninsula, 16.iii.1992, GD&MAS (QM); 1♂, Iron Range NP, Cape York Peninsula, 27.v.2010, WJ&RKP (WJC); 1♂, same data except, 26.v.-8.vi.??, JWCD (ANIC); 1♀, same data except 18-31.viii.1999; 1♀, same data except 4-12.vii.1995; 1♂, same data except 13.iv.1971, AA; 1♂, same data except -viii.1968, THG; 1♂, 1♀, Malanda, captive bred Indooroopilly, Brisbane, 30.xii.2009, TAL (TLIKC); 1♀, same data except AA180; 1♀, same data except AA178, em. 1.v.2010; 1♀, Mer Island, Torres Strait, 1.vi.1985, JFD (TLIKC); 1♀, same data except 30.ii.1986, MDB (TLIKC); 1♂, same data except 30.ii.1986, MDB (TLIKC); 1♀, same data except 9.iii.1995, TAL; 1♂, same data except 8-14.v.1998, JWCD (ANIC); 1♀, same data except 25.iv-5.v.1999, AIK (TLIKC); 1♂, same data except 25.i.2011, TAL&AIK; 1♂, same data except 28.i.2011, TAL&AIK; 1♂, same data except 29.i.2011, TAL&AIK; 1♀, same data except 9°54'S 144°02'E, 9.ii.2015, TAL&AIK; 3♂♂, Mt Cook NP, Cooktown, 12.x.1980, EDE (ANIC); 2♂♂, Mt Webb NP, -.ix.1980, EDE (ANIC); 1♀, Port Stewart Rd, Cape York Peninsula, 3.v.2003, WJ&DB (WJC); 1♀, Red Cliff, Cairns, 28.v.1973, JWCD (ANIC); 2♂♂, Somerset, 10.iv.1906 (ANIC); 1♂, 1♀, Thursday Island, 5.vi.1969, CWM (ANIC); 1♀, Trinity Park, N of Cairns, 1.xii.2009, ex captive ♀, JO (TLIKC).

NORTHERN TERRITORY: 5♂♂, 10♀♀, Rocky Bay, Gove, 3-7.v.1992, JWCD (ANIC); 1 ♀, Nhulunbuy, NT, Aug-Sept 1984, GW (ANIC).

Yoma sabina sabina (Cramer, [1780])

PAPUA NEW GUINEA: 2♂♂, Brown River, near Port Moresby, 9°15'S 147°05'E, 2.ii.1969, 15.ix.1975, HR (QM); 1♂, Kwikila, Central Province, 19.ii.1976, GRF (GRFC); 1♂, Rigo, PNG, 17.x.1968, GRF (GRFC); 4♂♂, 5♀♀, Kapa Kapa, Central Province, 9°48'S 147°31'E, 20.xi.1967 (♀), 14.xi.1968 (♀), 21.xi.1968 (♂), 26.xii.1968 (♀), 2.ii.1969 (♂), 6.ii.1969 (♂, 2♀♀), 23.xi.1973 (♂), HR (QM); 6♂♂, same data except 4.viii.1968 (♂), 10.viii.1968 (♂), 11.viii.1968 (2♂♂); 3.ii.1969 (2♂♂), 6.ii.1969 (3♂♂), GRF (GRFC); 4♂♂, same data except, 16.iv.1973 GRF (GRFC); 1♀, Kapa Gese, Central Province, PNG, 19.ii.1976, GRF (GRFC); 1♀, Kwikila, Central Province, 19.ii.1976, GRF (GRFC); 1♂,1♀, Paga Hill, Port Moresby, 18.i.1966, ex pupa, EM (QM); 1♂, same data except 19.i.1966; 1♂, Port Moresby, PNG, 3.ii.1971, GRF (GRFC).

Yoma algina (Boisduval, 1832)

QUEENSLAND: 1♂, 1♀, Claudie River, JAK (AM); 1♂, Heathlands, Cape York Peninsula, 11°45'S 142°35'E 15-26.i.1992, TAW&IDN (ANIC); 1♀, Iron Range, Cape York Peninsula, 1-9.vi.1971, GBM (QM); 1♂, 1♀, Iron Range, 25.v.1973 (♂), 28.v.1973 (♀), CGM (CGMC); 1♂, bred as *Y. sabina*, MDB, labelled 'ex breeding stock supposed to originate from Iron Range Qld, set Nov. 1990, original stock probably PNG' (TLIKC); 1♀, Lockerbie Area, Cape York Peninsula, 13-27.iv.1973, GBM (QM); 1♀, captive bred, ex. Melbourne Zoo colony, em. 21.xi.2009, TAL, Host *Hemigraphis* (TLIKC); 4♂♂, 9♀♀, same data except, em. 1.xii.2009 (2♀♀), 21.xii.2009 (1♂, 1♀), 22.xii.2009 (2♂♂, 2♀♀), 23.xii.2009 (1♂), 8.vi.2010 (1♀), 10.vi.2010 (1♀), 10.xi.2010 (1♀), 23.xii.2010 (1♀); 1♂, same data except AA168; 1♂, same data except AA1176; 1♂, same data except 30.iv.2010, AA170; 1♂, same data except 1.v.2010, AA171; 1♂, Peach Creek, 25 km NNE of Coen, 2.xi.1979, MSM&BJM (AM); 1♂, Philip Hill, Iron Range, 10.i.1994 RGE (HUC); 1♂, Somerset, Cape York Peninsula, Lep 11424, 10. iv. 1906, 'doubtfully Australian, GAW' (MV).

Yoma algina netonia Fruhstorfer, 1912

PAPUA NEW GUINEA: 1♂, Bulolo, Morobe Province, 20.i.1970, LR (QM); 1♂, Gabensis, Morobe Province, 7.vii.1973, GRF (GRFC); 1♂, Kapa Kapa, Kokoda Track, Central Province, 15.iv.1968, HR (QM); 2♀♀, Laloki, Central Province, 18.ii.1976, GRF (GRFC); 1♂, Rigo, Central Province, 15.x.1968, GRF (GRFC); 1♂, same data except 16.x.1968; 1♂, Wau, Morobe Province, 26.iii.1978, GRF (GRFC).

Results

Larval host plants

Larvae of *Y. s. parva* would not feed on *Hemigraphis* spp when young but when larger readily accepted this host. All larvae of *Y. algina* fed freely on *Hemigraphis* spp but refused to feed on *D. prostatus*. Thus, the results indicated larvae of *Y. algina* to be host specific to several species of just *Hemigraphis* and furthermore these larvae would not accept *Dipteracanthus* spp. In addition, larvae of *Y. s. parva* differed greatly from those of *Y. algina* in that they readily accepted *D. prostatus* and only as large larvae accepted *H. alternata* and *H. ciliata*.

Life histories

Yoma sabina parva (ex Malanda and Trinity Park)

Egg (Fig. 1): (n = *ca* 40); dome shaped; smooth with 14 vertical ribs.

First instar larva (Fig. 2): (n = *ca* 40); head shiny black, covered in pale olive-green setae, with two short blunt black horns; body cylindrical, dorsal surface black, ventral surface with last abdominal and anal segment yellow-green and semi-translucent; mesothorax, metathorax and abdominal segments each with six branched spines with bristles, with the lateral basal spine and another single bristle below each spiracle; prolegs yellow-green, legs black.

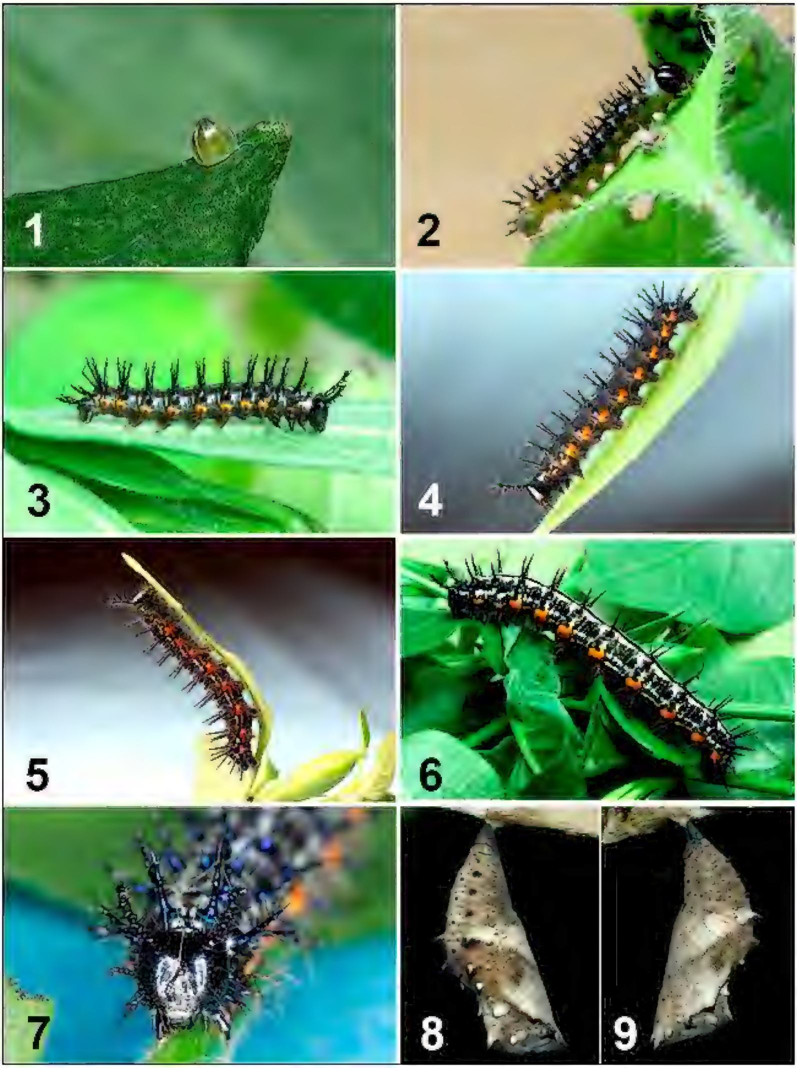
Second instar larva (Fig. 3): (n = *ca* 40); head as in first instar except setae black and horns longer; body as in first instar, shiny black with branched spines longer, with basal lateral spine originating from a circular bright orange patch; prolegs and legs black.

Third instar larva (Fig. 4): (n = *ca* 30); similar to second instar except spines longer and more branched, body with ventral bristly setae, a faint white lateral line joining orange patches and a pair of faint dorsal parallel white stripes running the full length of the body.

Fourth instar larva (Fig. 5): (n = 24); similar to third instar except body covered with many bristly setae, a definite white lateral line intermittently running the length of the body just above the setae, a faint lateral orange line joining orange patches and dorsally a defined pair of white parallel stripes running the length of the body.

Fifth instar larva (Fig. 6): (n = 24); similar to fourth instar except pair of spiny horns on head longer than the basal width between the two horns (Fig. 7); body black, smooth with noticeable white blotches forming two indefinite parallel lateral white lines and two indefinite parallel dorsal white lines, these dorsal white lines creating a noticeable dorsal black stripe between them; dorsal and lateral surfaces of body densely covered with fine white setae; dorsal black spines with a blue lustre with bases of spines blue.

Pupa (Figs 8-9): (n = 24); mottled brown and grey; anterior end with two projections; mesothorax with a sharp 90° dorsal ridge, two sharp lateral projections on edge of each wing case; with metathorax and abdominal segments possessing pairs of blunt spines; those spines on metathorax and abdominal segments 1 and 2 white; the largest spines being on abdominal segments 3 and 4, with pairs of large black and very small white blunt spines on abdominal segment 3, those on remaining abdominal segments blunt and black.



Figs 1-9. Early stages of *Yoma sabina*, Malanda, Qld: (1) egg (height 1 mm); (2) 1st instar larva (length 7 mm); (3) 2nd instar larva (10 mm); (4) 3rd instar larva (18 mm); (5) 4th instar larva (40 mm); (6) 5th instar larva (45 mm); (7) 5th instar larval head capsule (5 mm wide); (8-9) pupa, lateral views (height 25 mm).

Yoma algina (ex Melbourne Zoo Butterfly House)

Egg (Fig. 10): (n = circa 50); dome shaped; smooth with 14 vertical ribs.

First instar larva (Fig. 11): (n = 18); head shiny black, covered in cream-coloured setae, with two short blunt black horns; body cylindrical, dorsal and ventral surfaces black, with ventral surface, last abdominal and anal segment orange and semi-translucent; mesothorax, metathorax and abdominal segments each with six branched spines with bristles, with the lateral basal spine and another single bristle below each spiracle; prolegs orange, legs black.

Second instar larva (Fig.12): (n = 18); head as in first instar except setae black and horns longer; body shiny black with branched spines much longer than instar 1, with basal lateral spine originating from a circular dark orange patch; prolegs brown and legs black.

Third instar larva (Fig. 13): (n = 18); similar to second instar except spines on body longer and more branched; body glabrous, with bristly setae on ventral surface and a pronounced white lateral line joining orange patches; prolegs brown with bases black.

Fourth instar larva (Fig. 14): (n = 18); similar to third instar with white lateral line more pronounced.

Fifth instar larva (Fig. 15): (n = 18); similar to fourth instar except pair of spiny horns on head as long as the basal width between the two horns (Fig. 16), body non-glabrous with dorsal and lateral surfaces densely covered with fine white setae and bases of dorsal spines with a faint blue spot; body with a pronounced cream-coloured lateral line.

Pupa (Figs 17-18): (n = 18); mottled brown; anterior end with two projections; mesothorax with a sharp 90° dorsal ridge, two sharp lateral projections on edge of each wing case; metathorax and abdominal segments possessing pairs of sharp spines; those spines on metathorax (being large) and abdominal segments 1 and 2 white; the largest spines being on abdominal segments 3 and 4, with pairs of large brown and very small brown sharp spines on abdominal segment 3; those on remaining abdominal segments brown, sharp and curved upwards.

Comparison of larvae and pupae

The most notable differences between final instar larvae of the two species are the positions of white or cream lines on the thoracic and abdominal segments (Figs 6, 15): final instar larvae of *Y. s. parva* bear two ill-defined parallel dorsal white lines (Fig. 6), while those of *Y. algina* bear a pronounced cream-coloured lateral line (Fig. 15). In addition, final instar larvae of *Y. s. parva* are overall paler in colour, bear fewer setae and are more glabrous in body appearance than those of *Y. algina*, which appear darker, bear more setae and have a more hirsuite body texture.

Figs 10-18. Early stages of *Yoma algina*, Melbourne Zoo culture: (10) egg (height 1 mm); (11) 1st instar larva (length 6 mm); (12) 2nd instar larva (9 mm); (13) 3rd instar larva (20 mm); (14) 4th instar larva (30 mm); (15) 5th instar larva (45 mm); (16) 5th instar larval head capsule (6 mm wide); (17-18) pupa lateral views (height 24 mm).

The younger instars (2, 3 and 4) of both species were also found to have distinctive morphological differences (Figs 3-5, 12-14).

The final instar head capsules of both species are covered in facial setae and bear two black horns. The *Y. algina* head capsule (Fig. 16) has more facial setae than *Y. s. parva* (Fig. 7) and the horns of *Y. algina* (Fig. 16) are thicker than those of *Y. s. parva* (Fig. 7).

The pupae of the two species are notably different in the pattern of thoracic and abdominal spines, with pupae of *Y. algina* bearing much heavier and longer spines (Figs 17-18) than those of *Y. s. parva* (Figs 8- 9). The pupae of both species vary in colour, ranging from brown to dark grey, each with white blotches.

Overall, our descriptions and illustrations of the immature stages of *Y. s. parva* matched the illustrations of *Y. s. sabina* provided by Saguru and Haruo (2000).

Comparison of wing pattern elements

Superficially, adults of the two *Yoma* species (Figs 19-32) resemble each other but individuals can be readily separated using several wing pattern elements. Thus, the upperside orange colour of both sexes of *Y. algina* is much brighter and more vibrant (Figs 27-30, 32) than that of *Y. s. parva* (Figs 19-26, 31). Specifically for females, there are two orange spots in the subapical forewing area of *Y. s. parva* (Figs 20, 22, 24-26), while the same spots in *Y. algina* are white (Figs 28, 30, 32). Additionally, in females the hindwing uppersides of *Y. algina* always bear distinct ocelli in the orange submarginal areas (Figs 28, 30, 32).

On the underside, the wing patterns of *Y. s. parva* are much more variable than those of *Y. algina*, with *Y. s. parva* possessing submarginal black spots (Fig 19-26) rather than distinct ocelli in the same wing areas of *Y. algina* (Figs 27-30). Moreover, both sexes of *Y. algina* always possess a broad underside white band (Figs 27-30).

The shape of the forewing apex of both species differs, being pronounced and falcate in *Y. s. parva* (Figs 19-26, 31) and only slightly projected in *Y. algina* (Figs 27-30, 32). This is also the case for the short and blunt terminal tail on the hindwing, that of *Y. s. parva* being relatively long but almost absent in *Y. algina*.

Finally, based on the review of 29 specimens (21♂♂, 8♀♀) of *Y. s. sabina* from Papua New Guinea and 94 specimens (47♂♂, 47♀♀) of *Y. s. parva* from Australia, plus their variability in general, we found no consistent upperside wing pattern elements that can be used to confidently separate the two subspecies. In addition, the underside wing patterns of both populations are so highly variable that no differentiation between the two populations could be made using wing underside patterns.

Figs 19-24. *Yoma sabina* (all figures not to scale, upperside left, underside right). (19, 21, 23) ♂♂: (19) Malanda, Qld, 30.xii.2009, TAL [forewing length 38 mm]; (21) Dauar Island, Torres Strait, Qld, 12.ii.2015, TAL [42 mm]; (23) Mer Island, Torres Strait, 25.i.2011 TAL&AIK [41 mm]. (20, 22, 24) ♀♀: (20) Malanda, Qld, 30.xii.2009, TAL [42 mm]; (22) Dauar Island, 12.ii.2015, TAL [39 mm]; (24) Mer Island, 30.ii.1986, MDB [38 mm].

Figs 25-30. *Yoma* spp (all figures not to scale, upperside left, underside right). (25-26) *Yoma sabina* ♀♀: (25) Cairns, Qld, 30.xii.2008, TAL [forewing length 42 mm]; (26) Green Hill, Thursday Island, Torres Strait, 20.ii.1994, TAL [36 mm]. (27-30) *Yoma algina*: (27) ♂, ex Melbourne Zoo colony, em. 22.xii.2009, TAL [35 mm]; (28) ♀, ex Melbourne Zoo colony, em. 10.xi.2010, TAL [39 mm]; (29) ♂, Iron Range, Qld, 1990, MDB [35 mm]; (30) ♀, ex Melbourne Zoo colony, em. 22.xii.2009, TAL [38 mm].

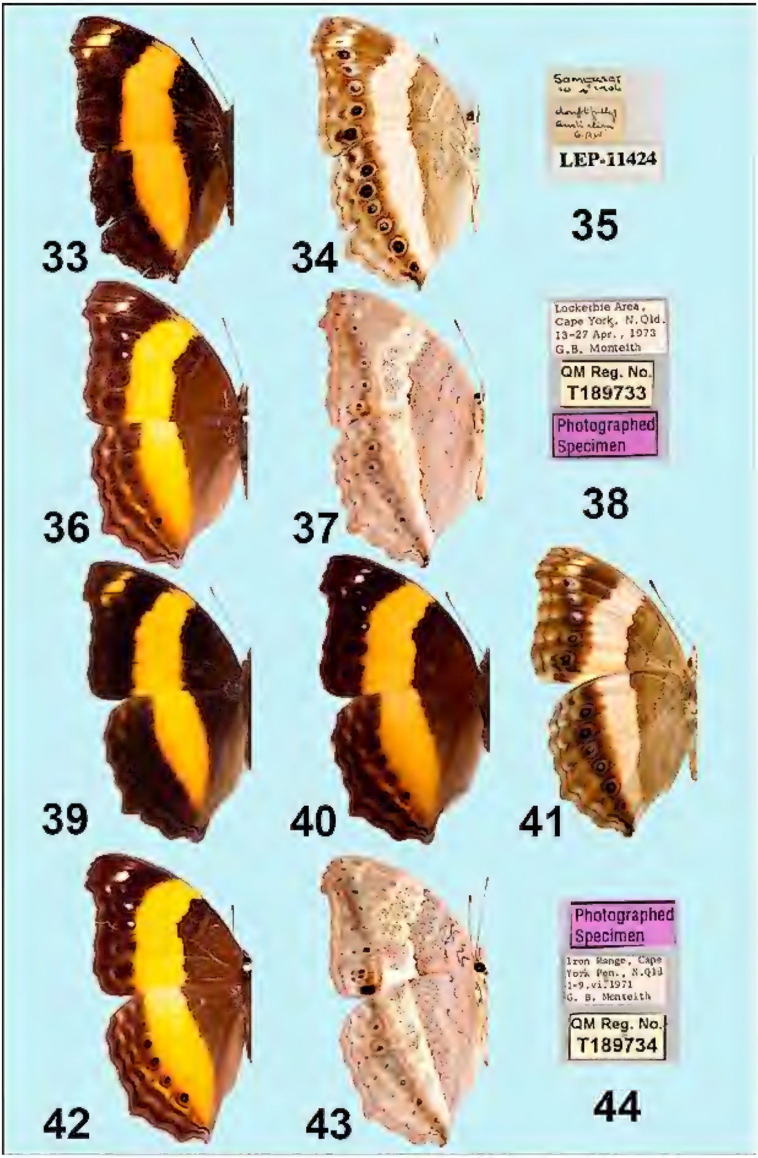
Figs 31-32. Live adults of *Yoma* spp in captivity in typical perched positions on forest edges (figures not to scale): (31) *Y. sabina* ♂ [forewing length 42 mm]; (32) *Y. algina* ♀ [40 mm]. (Photographs courtesy of G. Sankowsky, Tolga).

Request for data from butterfly collections

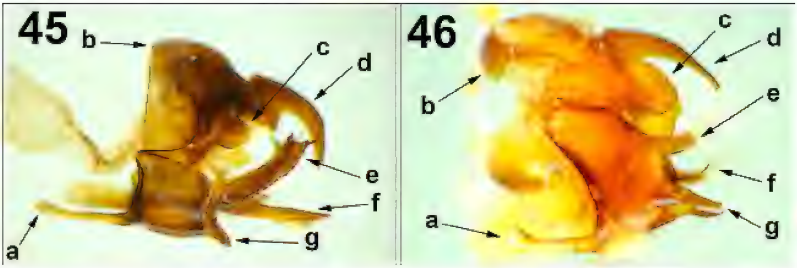
The request for collection data from institutional (4 out of 4 responded) and private collections (7 out of 8 responded) produced 10 specimens (in three institutional and two private collections) of wild caught *Y. algina* (6 ♂♂, 4 ♀♀), all from Cape York Peninsula, Queensland (Figs 33-44). The collection data further indicated that the specimens all originated from the east coast of Cape York Peninsula, *i.e.* extending north from Peach Creek Crossing near Coen, through Claudie River, Iron Range and Heathlands, to Somerset and Lockerbie at Cape York. Over half the specimens (6) originated from the Claudie River basin (Figs 39-44) and the earliest known specimen was collected in 1906 at Somerset (Figs 33-35, in MV). All five locations contain tracts of rainforest or semi-deciduous monsoonal vine thicket. Other wild caught specimens not illustrated are: ♂, ♀, Claudie R, 1914 (AM); ♂, Peach Ck, 25 km NNE of Coen, 1979 (AM); ♂, Heathlands, 1992 (ANIC); ♂, Philip Hill, Iron Range, 1994 (HUC).

Comparison of male genital armature

The male genital armature (Figs 45-46) of the two species are markedly different, with just about all structures distinctly dissimilar. Most notable are: the relatively small claspers (valvae) of *Y. algina*; the relatively very thin apical tip of the phallus (aedeagus) of *Y. s. parva*; the unique structure of the gnathos of each species is very diagnostic, that of *Y. algina* being very large with spines; although the unci in both species are hook-shaped, the uncus of *Y. algina* is much more so. There are also noticeable differences in the shapes of the tegumen, vinculum and saccus of each species. Aside from these differences, Parsons (1998) reiterated the comment by Fruhstorfer (1912-1915) on the general complexity of the structures of the male genitalia of *Yoma* spp. This study certainly found the same, particularly the complicated structure of the clasper, uncus and gnathos (Figs 45-46: c, d and e respectively).



Figs 33-44. Some of the wild caught Australian specimens of *Yoma algina* with their origins (all Cape York Peninsula) and repositories: (33-35) ♂, Somerset, 1906 (MV); (36-38) ♀, Lockerbie, 1973 (QM); (39-41) ♂, ♀, Iron Range, 1973 (CGMC); (42-44) ♀, Iron Range, 1971 (QM); forewing lengths of specimens were not recorded.



Figs 45-46. Male genital armature, lateral left view, dorsal surface uppermost: (45) *Yoma algina*, ex Melbourne Zoo culture, captive bred Indooroopilly, Brisbane, Qld, 10.vi.2010, TAL, host *Hemigraphis* (TLIKC); (46) *Yoma sabina*, Green Hill, Thursday Island, Torres Strait, 3.iii.2004, AIK (TLIKC). Approximate widths of genitalia including saccus = 5 mm; names of structures labelled are: a – saccus, b – tegumen, c – clasper, d – uncus, e – gnathos and f – phallus.

Discussion

In the early 1980s, a stock of *Y. algina* (believed at the time to be *Y. s. parva*) was used to commence a commercial butterfly house culture of *Yoma*. Despite the adults of both species being similar in their wing pattern elements, the individuals of *Y. algina* flying in the butterfly houses appeared, in general, to be much brighter in appearance than *Y. s. parva*, with a more intense and vibrant orange colouration on the upperside of the wings, particularly in the males. Because very few individuals of *Y. s. parva* had been reared at that time, it was thought that the brightness of individuals reared in butterfly houses was perhaps related to the fresh colour of newly eclosed individuals.

The question remains, where did the butterfly house culture stock of *Y. algina* originate? When first identified, this species was not known from Australia and it was presumed that livestock originated from Papua New Guinea. Initial discussions with several collectors and butterfly workers suggested that the *Yoma* culture first established in the Melbourne Zoo Butterfly House came from live material collected either from Iron Range by G. Wood (as per Wood 1987a), or from Weipa by the late Charles McCubbin who, just prior to his death in 2010, told one of us (RK) that he collected live *Yoma* females from Weipa for the Melbourne Zoo in the early 1990s, not long after the zoo established its butterfly house, although *Yoma* is still unrecorded from Weipa (Braby 2000, 2016). G. Sankowsky (pers. comm.) rejected the latter claim and stated that Graham Wood, who was working at Iron Range in the 1980s, sent him a gravid female and resulting progeny were supplied to the Australian Butterfly Sanctuary at Kuranda, Queensland and, subsequently, to the Melbourne Zoo in the late 1980s. Based on this latter information, the most plausible scenario is that Melbourne Zoo's *Y. algina* most likely originated from Iron Range, Cape York Peninsula, in the late 1980s.

The review of *Yoma* specimens in public and private collections indicated that, in Australia, *Y. algina* occurs sympatrically with *Y. s. parva* exclusively in eastern Cape York Peninsula, roughly from McIlwrath Range (*i.e.* Peach Creek Crossing) near Coen, north to the tip of Cape York Peninsula (*i.e.* Somerset). The distributions of the two species are also known to overlap in southern Papua New Guinea (Parsons 1998). The true taxonomic identity of this isolated Australian population of *Y. algina* will remain uncertain until a more thorough revision is made, particularly of material from New Guinea and until more wild-caught Australian specimens become available. The Australian population is tentatively assigned here to the southern Papua New Guinean subspecies *Y. a. netonia* (Parsons 1998), based solely on the geographical proximity of eastern Cape York Peninsula to southern Papua New Guinea.

The introduction of *Y. a. netonia* from Iron Range into the butterfly houses in eastern Australia added a degree of misunderstanding in the literature, particularly with the life history and identification of *Y. s. parva*. Wood (1987a) was confused with the host plants that he used to rear what he thought at the time to be *Y. s. parva*. He illustrated, in monochrome, a final instar larva that he identified as *Y. s. parva*, but which clearly matches the mature larva of what we now know to be *Y. a. netonia*. A similar mistake, this time in identifying the adults, was perpetuated by several authors who illustrated *Y. a. netonia* instead of *Y. s. parva* in their publications on Australian butterflies (*viz.* Valentine 1988, Braby 2000, 2004, 2016, Orr and Kitching 2010).

Currently, the immature stages of *Y. a. netonia* have not been found in the wild in Australia but, based on our host plant preference experiments, *Hemigraphis* appears to be the preferred host plant. Based on records from G. Sankowsky (pers. comm.) and Australia's Virtual Herbarium (2016), *H. ciliata* appears to be the sole native Australian species of *Hemigraphis* occurring in Queensland. Current records indicate that *H. ciliata* is restricted to the eastern side of Cape York Peninsula, mostly from the Pascoe River to the Rocky River in damp shady areas in very well developed rainforest, although there are a few records of it further south around Cape Tribulation. These distribution records, albeit in all probability incomplete, correlate roughly with the known distribution of *Y. a. netonia* in Queensland. If *H. ciliata* is the native host, then *Y. a. netonia* might also occur further south around Cape Tribulation in the Wet Tropics.

Hemigraphis alternata is a naturalised species thought to originate in Java, Indonesia. Australia's Virtual Herbarium (2016) records indicate that it is currently known from tropical Queensland, between Port Douglas and Cooktown and near Almaden. Other *Hemigraphis* spp in cultivation in Queensland include *H. reptans* (Roth) J.R.J. Wood from the Pacific Islands and *H. urens* from India. A cultivated *Hemigraphis* sp. is reported to be common in gardens and council plantings in the wet tropical lowlands of northern Queensland (G. Sankowsky pers. comm.).

Several native *Dipteracanthus* spp are recorded from tropical Australia (Australia's Virtual Herbarium 2016), including *D. australasicus* F. Muell. from much of tropical Australia and *D. bracteatus* from tropical Queensland north of Cairns, the Top End of the Northern Territory and in Torres Strait. The distribution of *D. bracteatus* roughly matches that of *Y. s. parva*. In addition, G. Sankowsky (pers. comm.) has reared *Y. s. parva* on *Brunoniella australis* (Cav.) Bremek (Acanthaceae), which occurs widely throughout eastern Australia and the Northern Territory (Australia's Virtual Herbarium 2016) and therefore could be a natural host plant of *Y. s. parva* in the Queensland tropics, including Iron Range. Braby (2016) recorded *B. spiciflora* (F.Muell. ex Benth.) Bremek as a host of *Hypolimnas alimena lamina* Fruhstorfer, 1903 (Nymphalinae: Junoniini) in Australia.

Based on his knowledge of *Yoma* in Cape York Peninsula, G. Sankowsky (pers. comm.) further indicated that, in the wild, the two *Yoma* spp are separated by disparate ecotones: *Y. s. parva* generally occurs in a variety of habitats from more open forest to lowland rainforest (Valentine 1988) where *D. bracteatus* and *B. australasicus* grow, while *Y. a. netonia* is restricted to rainforest where *H. ciliata* grows.

Although *Y. s. parva* is well known from mainland Australia (Braby 2000, 2016), much less is known of its distribution throughout Torres Strait, where the species appears to be confined to islands with stands of semi-deciduous monsoon or vine forest. These islands include: in the south of the strait, Thursday (Waiben) (Waterhouse and Lyell 1914, Lambkin and Knight 1983, De Baar 1988, Valentine 1988), Horn (Ngurupai) (unpublished data, T.A. Lambkin: December 1993, January 1994), Prince of Wales (Muralug) (Waterhouse and Lyell 1914) and Hammond (Keriri) (unpublished data, T.A. Lambkin: April 1989); in the central region, Moa (Waterhouse and Lyell 1914, Valentine and Johnson 1993); in the east, Darnley (Erub) (Waterhouse and Lyell 1914, Johnson 1983), Murray (Mer) (Waterhouse and Lyell 1914, Wood 1987b, Lambkin and Knight 1990) and its neighbouring island Dauar (TLIKC); and Dauan Island (TLIKC) in the north. A useful map indicating the positions of these islands and others in Torres Strait is illustrated in Braby (2000: p. 17).

In this study, evidence from several data sources, *i.e.* larval colour pattern, morphology and host plant requirements, pupal morphology, adult wing shape, colour pattern elements and male genitalia, support a specific distinction between the two taxa, based on the principles of the species concept (de Queiroz 2007). Although the two species are similar in their biology and biotype requirements and share some sympatry in their geographical distributions, our investigations identified at least 22 phenotypic character states that the two taxa do not share.

Six character states were found in the final instar larvae that differentiated the two species: the pattern and position of cream-coloured lines on, and the basal colour and texture of, the thoracic and abdominal segments; the degree of thoracic and abdominal setae; and, on the head, differences in the degree of facial setae and thickness of the horns. There was at least one character state that differentiated the pupae, with the thoracic and abdominal spines of *Y. a. netonia* being heavier and longer that those of *Y. s. parva*. Differences in wing pattern elements (*i.e.* colour, pattern arrangement and shape) between the two taxa were notable, with seven character states that differed between the two species. The male genitalia of the two taxa are dissimilar in the shape and size of the claspers, phallus, gnathos, uncus, tegumen, vinculum and saccus (seven character state differences). Finally, *Y. a. netonia* appears to be host specific to *Hemigraphis* spp (another character state difference).

This study also highlighted the similarity of the nominate subspecies of *Y. sabina* to the Australian taxon *Y. s. parva*. Both taxa meet at a theoretical line situated on the southern coast of Papua New Guinea: to the north of this line is *Y. s. sabina* while to the south is *Y. s. parva*. We questioned the basis of this separation during our study of *Y. sabina* from Australia and Papua New Guinea. Thus, our review of the description of *Y. s. parva* by Butler (1876) has revealed that his description (as *Rhinopalpa parva*) was based, in all probability, on a single male specimen (Edwards *et al.* 2001) collected at Cape York by Rev. J.S. MacFarlane. More interestingly, Butler's (1876) description matches the wing pattern elements of a phenotypically distinct, diminutive 'dry season form' referred to by Waterhouse and Lyell (1914) (Figs 47-48). This form is typically observed just after the commencement of the first rains of the monsoonal wet season.

Figs 47-48. *Yoma sabina sabina* form *parva* (figures to scale, upperside left, underside right): (47) ♂, Dauar Island, Torres Strait, Qld, 12.ii.2015, TAL [forewing length 30 mm]; (48) ♀, Dauar Island, Torres Strait, Qld, 11.ii.2015, TAL [forewing length 34 mm].

It is obvious now that Butler (1876) had before him a specimen of this form, even remarking at the end of his description that 'This is the smallest *Rhinopalpa* that I have seen' and based his description of *parva* on this specimen, not on what is the more typical 'wet season' *Y. sabina* that occurs in Australia and Papua New Guinea (Figs 19-26). Being smaller in size is one of the key characters of the 'dry season form', having more orange in the sub-marginal areas of the forewing upperside and, in the male, possessing a distinctive tawny spot in the upperside forewing cell, all features that Butler (1876) described. This diminutive form is now known from both Papua New Guinea (Parsons 1998) and Australia (Braby 2000).

Thus, our study validates Fruhstorfer (1912-1915), Barrett and Burns (1951), Parsons (1998) and Tennent (2002) in their treatment of the two taxa as distinct species and, moreover, confirms the natural occurrence of *Y. a. netonia* on mainland Queensland. Based on the known distributions of the larval hosts in Cape York Peninsula and beyond into the Wet Tropics and possibly Torres Strait, the distribution of *Y. a. netonia* may be more extensive than current collection records indicate.

In addition, the staggered distribution of *Y. s. parva* across Torres Strait is likely an artefact of butterfly collecting efforts on specific islands, with some inhabited islands with suitable habitats still not surveyed well for butterflies. Thus, *Y. s. parva* in Torres Strait is also probably more widespread than presently known and this distribution is almost certainly related to the distribution of its larval host plants (*Dipteracanthis* spp and possibly *Brunoniella* spp).

Furthermore, based on our review of *Y. sabina* from Papua New Guinea and Australia, it was found that the two populations differed little phenotypically and, accordingly, we regard the subspecies *Y. s. parva* (Butler, 1876), **syn. nov.** as a junior synonym of *Y. s. sabina*. Provisionally, until a proper revision of the 'dry season form' is undertaken, we also propose this diminutive 'dry season' form as *Y. s. sabina* form *parva* **stat. rev.**

Finally, further intensive collecting of *Yoma* spp may reveal the presence of *Y. a. netonia* in areas such as the western side of Cape York Peninsula, in the Wet Tropics and in the southern Torres Strait, in particular on the southern islands of Prince of Wales and Hammond. These two islands have extensive areas of suitable habitat and have been visited relatively infrequently by butterfly workers.

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Appendix I

Specifics of the request for data from butterfly collections to ascertain the existence of wild caught specimens of Australian *Y. algina*:

'A recent examination of several purported Australian specimens indicates that two species of *Yoma* could occur in Australia, *viz. Y. sabina* and *Y. algina*. *Yoma algina* is predominately a New Guinean species and superficially resembles *Y. sabina*. In general, the underside wing pattern of *Y. algina* is less variable than *sabina*; the orange colouring of the *algina* male is brighter than *sabina*; the forewings of *algina* are less falcate and in the underside submarginal areas *algina* has ocelli instead of the black dots of *sabina*. Specifically, in the females, *algina* has submarginal ocelli on the upperside hindwings, and the apical markings of the forewing upperside are white instead of orange as in the female of *sabina*. To help elucidate this issue and confirm if *Y. algina* naturally occurs in Australia, we would appreciate receiving collection data of *Yoma* spp, together with an identification based on the attached figures that show wing pattern differences between the two species and as outlined above.'